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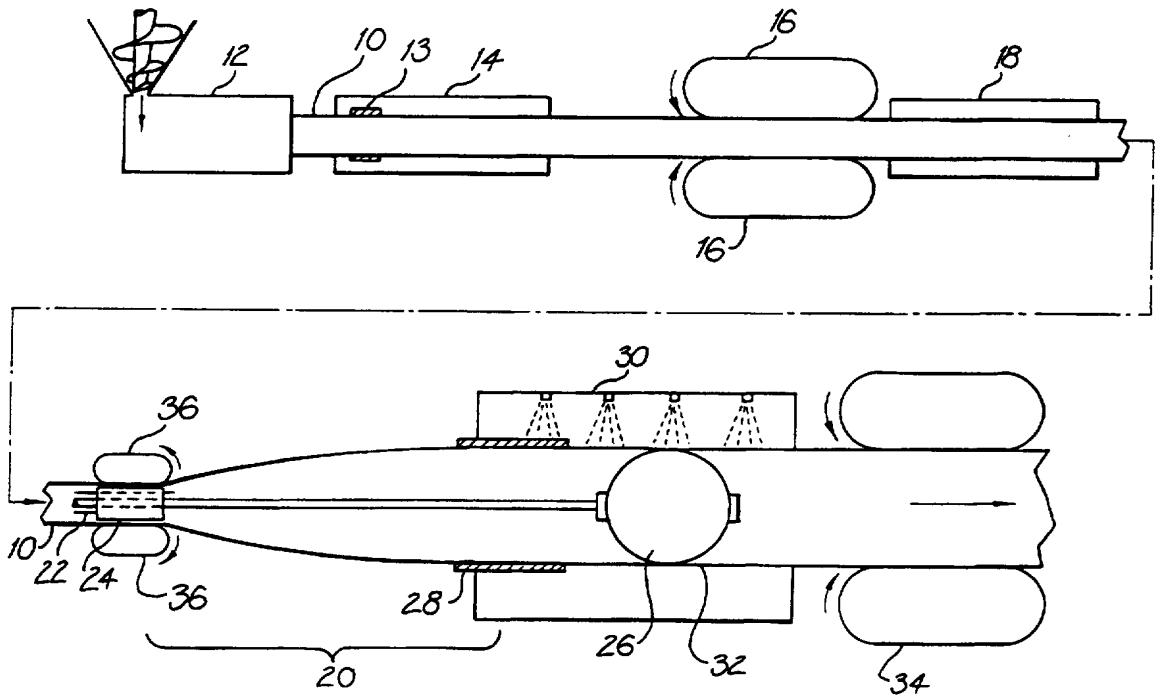
(54) Title: BIAXIAL STRETCHING OF PLASTIC TUBES



(57) Abstract

A continuous process and apparatus for producing oriented plastic tube comprising the steps of extrusion (12), temperature conditioning (18), diametrical expansion (zone 20) and cooling (30), characterised in the step of inducing axial draw of the tube between first (16) and second (25, 36) haul-off means located upstream of said expansion step (zone 20).

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BIAXIAL STRETCHING OF PLASTIC TUBES

BACKGROUND OF THE INVENTION

This invention relates to process and apparatus for the manufacture of oriented plastics tubes, and in particular to the manufacture of tubes which have been stretched (drawn) in both the circumferential and axial directions to orient the material in the direction of stretching and enhance its mechanical properties.

International Patent Application No. WO 90/02644 describes one process for the manufacture of thermoplastics tubes for example for unplasticised polyvinyl chloride (uPVC) which have a degree of orientation in the circumferential direction that improves properties such as resistance to hoop stresses, and renders the tubes particularly suitable for transmission of water under pressure. The process described in that patent application comprises:

(i) extruding a tube of plastics material;

(ii) temperature conditioning the extruded tube to bring it to a temperature suitable for expansion;

(iii) diametrically expanding the tube by application of an internal pressure to the tube that is limited at its downstream end by a plug that is inflatable or otherwise expandable to maintain pressure within the expansion zone; and

(iv) cooling the expanded tube to set the tube in its diametrically expanded configuration.

To pull the tube through this process line a first haul-off tractor is provided before the temperature conditioning zone and another haul-off tractor is provided downstream of the expansion and cooling zones. Axial draw may be introduced into the product by running the downstream tractor at a higher haul-off speed than the first.

Other processes have been proposed in which the diametrical expansion is achieved by drawing the tube over a solid mandrel. The present invention is applicable also to such processes.

SUMMARY OF THE INVENTION

In a first form, the invention provides a continuous process for producing oriented plastic tube comprising the steps of extrusion, temperature conditioning, diametrical expansion and cooling, characterised in the step of inducing axial draw of the tube between first and second haul-off means located before said expansion step.

A second form of the invention provides a process line for continuous production of oriented plastic tube, comprising an extruder for extruding a tube, temperature conditioning means for bringing the tube to a temperature suitable for expansion, expansion means for causing diametrical expansion of the extruded tube and cooling means for setting the tube in its diametrically expanded configuration, characterised in that first and second haul-off means are located upstream of the expansion means for inducing axial draw of the tube prior to said diametrical expansion.

The term "haul-off means" as used herein is to be

understood as referring to means which grip the tube and regulates the axial speed of the tube.

Preferably, the axial draw is induced prior to at least the completion of the temperature conditioning step. In one preferred form, the axial draw is induced concurrently with at least part of the temperature conditioning step. This may be achieved by locating said first haul-off means upstream (relative to the direction of tube travel) of a temperature conditioning zone and locating said second haul-off means between the temperature conditioning and expansion zones.

BRIEF DESCRIPTION OF THE DRAWINGS

Further preferred embodiments shall now be described with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of the tube manufacture and expansion process; and

Figure 2 is a schematic view showing an alternative embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to figure 1, the plastic tube 10 is produced by extruder 12 and is set to correct diameter by a sizing device, such as a sizing sleeve 13, within a primary cooling spray tank 14. The tube 10 is hauled from the extruder by a first haul-off tractor 16.

The tube 10 then proceeds to a temperature conditioning zone 18, in which the tube is contacted with a heat transfer medium such as water to attain a specific temperature profile across the tube wall, at which the subsequent diametral expansion of the tube

causes orientation of the polymer molecules principally in the circumferential direction. The orientation results in enhanced physical properties especially increased resistance to hoop stresses. The tube then enters an expansion zone 20 between a pair of plugs 24 and 26 held inside the tube by a service tube 22 connected back through the extruder head to a thrust restraint (not shown).

The first plug 24 - the upstream plug relative to the direction of travel of the tube 10 - is sized to fit tightly within the unexpanded tube 10. A series of control wheels 25 surrounding the tube circumference push the tube tightly on to the plug 24 so that there is sufficient seal to maintain pressure in the expansion zone.

In the illustrated embodiment, the control wheels 25 are controlled so that dictate the velocity at which the tube is fed into the expansion zone. This velocity is higher than that of the first haul-off tractor 16 so that a controlled degree of axial draw of the tube is induced before and/or within the temperature conditioning zone. In alternative embodiments, the control wheels 25 can be free running and a separate haul-off means, for example similar to haul-off tractor 16, can be added at the downstream end of the temperature conditioning zone, or a haul-off 36 can replace the wheels 25 at the upstream end of the expansion zone where the tube is internally supported by the upstream plug (see Fig. 2).

Achieving controlled axial draw in the tube wall prior to the expansion zone provides several benefits. Firstly, the thinning of the tube wall which occurs due to the axial draw makes the temperature conditioning more efficient so that greater

temperature uniformity around the tube wall can be achieved before expansion and/or a shorter temperature conditioning zone can be employed.

The thinning of the tube wall prior to expansion reduces the pressures and axial thrusts required for the diametral expansion, increasing the stability and controlability of the process. Furthermore, the material is delivered to the expansion zone at a set rate by the second haul-off means, further increasing stability and control.

It will be appreciated that the above advantages apply also to solid mandrel or other diametral expansion means and the present invention applies also to such processes. Also, the axial draw may be used to orient fibres or other particles (such as elongated fillers) in the tube wall, either in addition or as an alternative to producing axial molecular orientation of the polymer material.

The downstream plug 26 is inflatable so that its diameter can be changed from the unexpanded state to the expanded state in order to start the process. The plug 26 is inflated sufficiently to maintain pressure in the expansion zone while allowing some of the expansion fluid to flow past the plug and lubricate the plug within the moving tube. The service tube 22 has a pair of concentric tubes, one of which continues forward to carry inflation fluid, for example air, to the downstream plug 26 and the other supplying expansion fluid, preferably hot water, to the upstream plug, which then enters the expansion zone via outlets 27.

Between the two plugs the plastic tube 10 undergoes expansion in the radial direction due to the internal

pressure, without external restraint. Towards the downstream end of the expansion zone, there is provided a sizing sleeve 28 or other sizing device and a cooling spray tank 30 for setting the final diameter of the expanded tube 32. This is followed by a final haul-off tractor 34, which may be set at a higher speed than the second haul-off means 25 if it is desired to achieve additional axial orientation of the tube in the expansion zone, and cutting equipment (not shown). In practice some axial orientation of the tube will usually be generated in the expansion zone due to the axial force exerted on the expanded tube 32 by the final tractor 34. The axial force is required in order to counteract the axial force exerted on the tube in the opposite direction by the pressure of expansion fluid in the expansion zone 20.

The average axial draw of the tube over the whole process line is fixed by ratios of the first and final haul-off tractors. Axial draw may be introduced both in the expansion zone itself and in the pre-expansion zone between the first haul-off 16 and the driven wheels 25. Essentially no axial draw is introduced after the expansion zone as the tube has been cooled. Thus, at any time the sum of the axial draw being introduced in the expansion and pre-expansion zones will be equal to the haul-off ratios between the first and final tractors and therefore constant.

By means of the present invention, it is possible to achieve direct control over how much axial draw occurs in each zone. The inventors have found that this is important both to product consistency and the operation of the process itself.

While particular embodiments of this invention have been described, it will be evident to those skilled in

the art that the present invention may be embodied in other specific forms without departing from the essential characteristics thereof. The present embodiments and examples are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

CLAIMS

1. A continuous process for producing oriented plastic tube comprising the steps of extrusion, temperature conditioning, diametrical expansion and cooling, characterised in the step of inducing axial draw of the tube between first and second haul-off means located upstream of said expansion step.

2. A process according to claim 1 wherein the axial draw is induced prior to at least the completion of the temperature conditioning step.

3. A process according to claim 2 wherein the axial draw is induced concurrently with at least part of the temperature conditioning step.

4. A process according to claim 3 wherein said temperature conditioning step occurs within a temperature conditioning zone, said first haul-off means is located upstream of the temperature conditioning zone and second haul-off means is located between the temperature conditioning zone and an expansion zone.

5. A process according to claim 4 wherein the tube is internally supported in the region of said second haul-off means.

6. A process according to claim 1 further comprising inducing additional axial draw between said second haul-off means and further haul-off means located downstream of said expansion and cooling steps.

7. A process according to claim 1 wherein said

expansion is induced by internal fluid pressure retained between upstream and downstream plugs located within the tube.

8. A process according to claim 7 wherein said downstream plug is capable of diametrical expansion.

9. A process according to claim 7 wherein the downstream plug provides internal support to a part of the tube contacted by said second haul-off means.

10. A process line for continuous production of oriented plastic tube, comprising an extruder for extruding a tube, temperature conditioning means for bringing the tube to a temperature suitable for expansion, expansion means for causing diametrical expansion of the extruded tube and cooling means for setting the tube in its diametrically expanded configuration, characterised in that first and second haul-off means located upstream of the diametrical expansion means induce axial draw of the tube prior to said diametrical expansion.

11. A process line according to claim 10 further comprising further haul-off means located downstream of said expansion and cooling means for inducing additional axial draw to the tube.

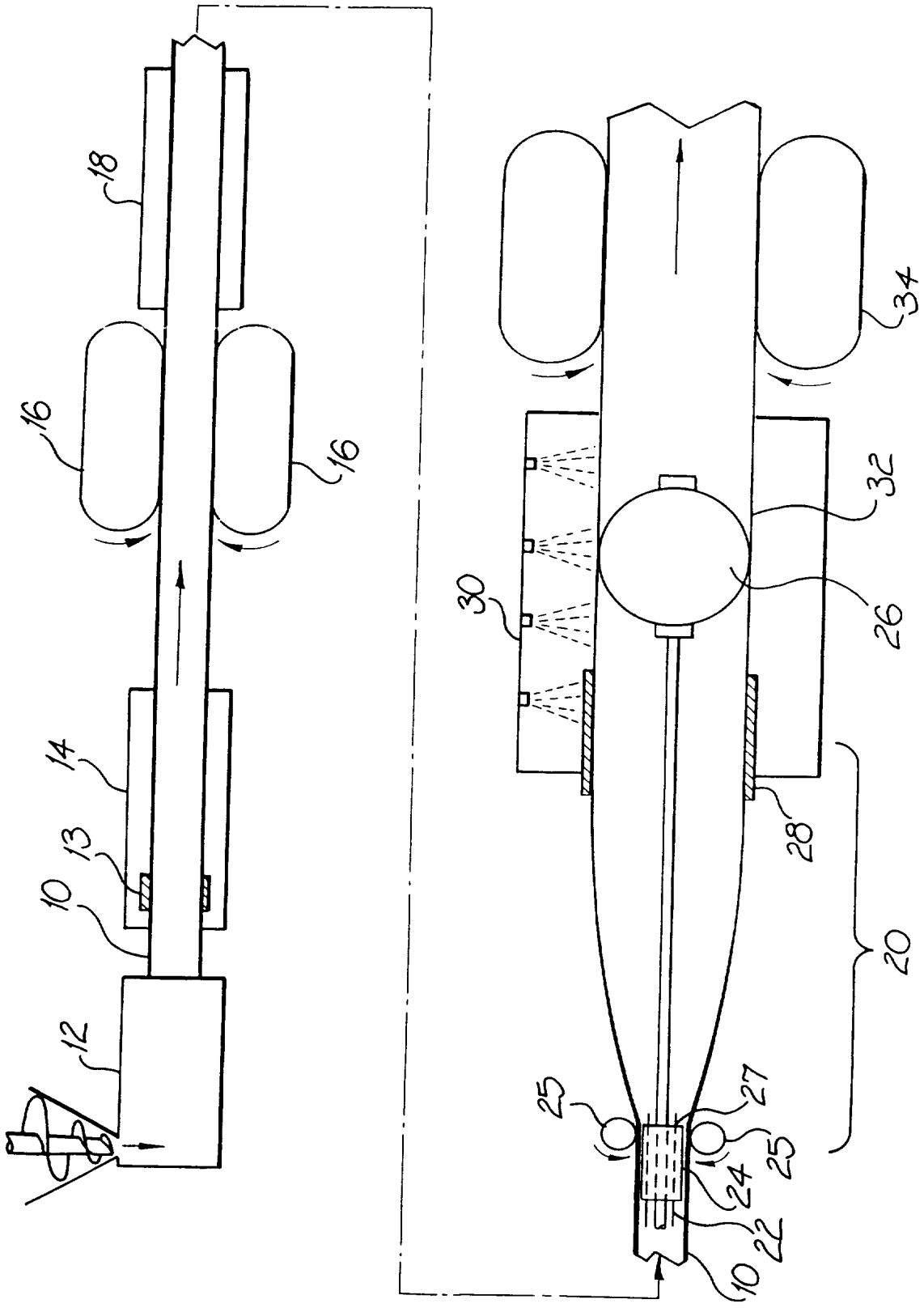

FIG. 1

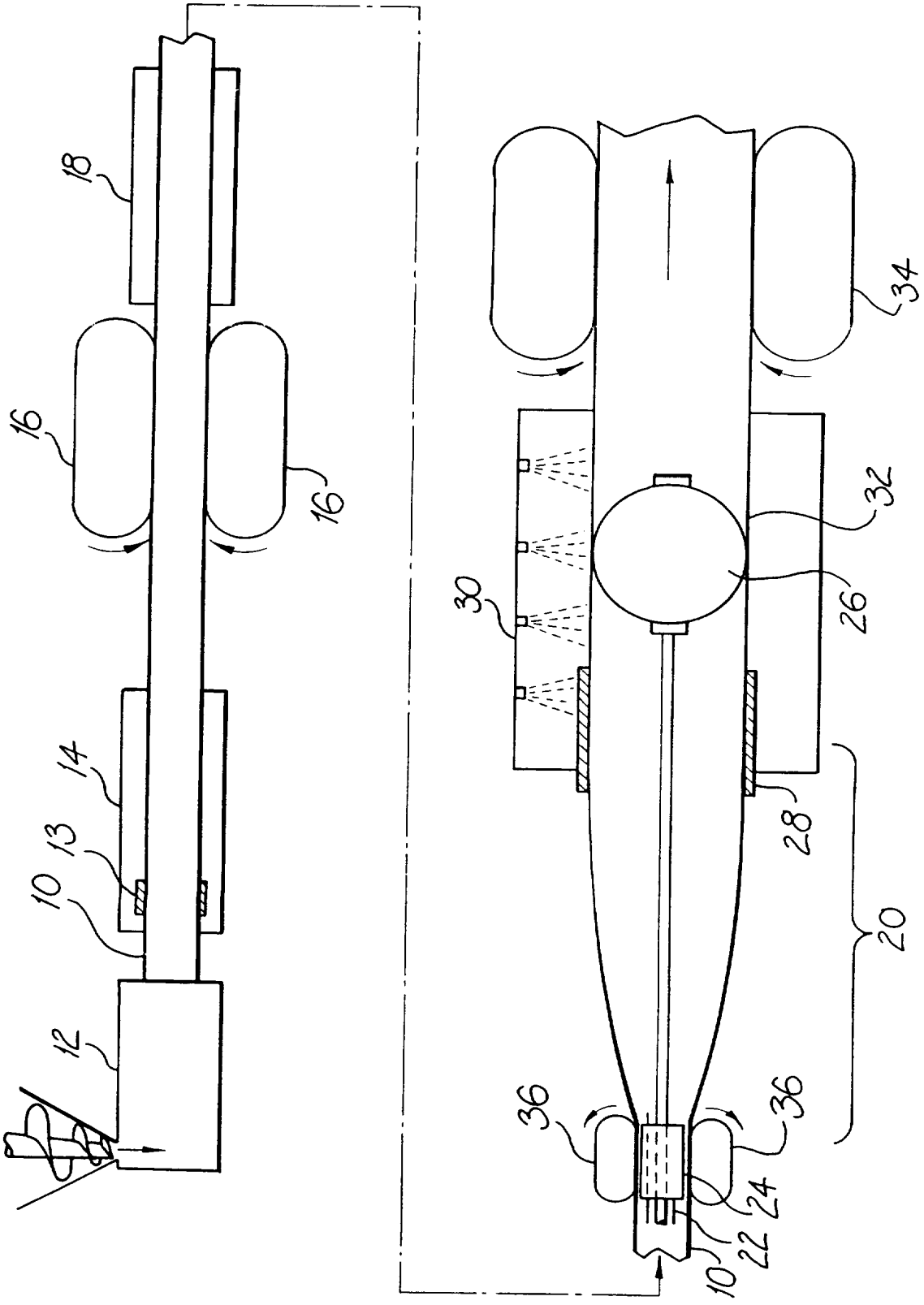

FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 96/00575

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: B29C 55/26, 47/88 // B29L 23:00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC (6): B29C 55/26, 47/88
IPC (3): B29C 17/02, B29F 3/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Patent Abstracts of Japan, M-44, page 31, JP 55-121016 A, (YOSHINO KKK) 17 September 1980.	
A	Patent Abstracts of Japan, M-1577, page 14, JP 5-329926A, (CCI KK) 14 December 1993.	
A	WO, 90/02644 A1, (VINIDEX TUBEMAKERS) 22 March 1990	

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

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Date of the actual completion of the international search	Date of mailing of the international search report
1 October 1996	30 OCT 1996
Name and mailing address of the ISA/AU AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (06) 285 3929	Authorized officer **David Lee** Telephone No.: (06) 283 2107

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C (Continuation) **DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE, 3903078 A1, (BARMAG AG) 17 August 1989	
A	US, 5322664 A, (BLACKWELDER) 21 June 1994	
A	EP, 468417 A2 (PHILLIPS PETROLEUM) 29 January 1992	
A, P	WO, 95/25626 A1, (WAVIN BV) 28 September 1995	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No.
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This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Member
JP 55-121016A	NONE
JP 05-329926A	NONE
WO 9002644	AU 43282/89
DE 3903078	NONE
US 5322664	NONE
EP 468417	JP 4226736 US 5151235
WO 9525626	AU 19620/95 NL 9400451

END OF ANNEX